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ABSTRACT

This project examined the use of quantitative statistical models to bridge the gap between commonly available university data and knowledge for decision making. A method using a multivariate statistical model is discussed in the context of academic quality in higher education. A "problem-oriented" data base designed to study quality and using quality determiners, quality indicators and proxy quality indicators was built using data from the 170 doctoral institutions in the United States. Using this tool, the study examined five institutional profiles: University of California-Berkeley, 1982 and 1986; University of California-Berkeley and Michigan State University, 1986; Average State of California Doctoral Institution, 1982 and 1986; Average State of Michigan Doctoral Institution, 1982 and 1986; and University of California-Berkeley 1986 Actual and Simulated Profiles. The paper suggests two ways of using data to improve decision making: (1) by showing how administrators could view the impact of their past decisions on the academic quality of their institutions; and (2) by simulating, for administrators, the impact of alternative decisions on the academic quality of their institutions. Concerning the profiles, the study noted the following characteristics; that they: are stable over time; reflect national trends; can uncover major institutional, state, and regional policy differences; show a high association between faculty compensation and faculty reputational quality; reflect the strength of the relationship between the Quality Determiners and the Quality Indicators, and reinforce the strategies currently used by high-quality universities. The paper includes 18 references and 5 tables. (JB)

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Using a Multivariate Statistical Model
to Bridge the Gap Between Data and Decision Making

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Jean Endo
Chair and Editor
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Abstract

This paper suggests the use of quantitative statistical models to bridge the gap between commonly available university data and knowledge for decision making. A method, which uses a multivariate statistical model, is discussed in the context of academic quality in higher education. The paper suggests two ways of using data to improve decision making: (1) by showing administrators the impact of their past decisions on the academic quality of their institutions and (2) by simulating, for administrators, the impact of alternative decisions on the academic quality of their institutions. Results are discussed, suggesting the existence of fundamental differences in policies among doctoral universities and a relationship between these policies and faculty reputational quality.

Using a Multivariate Statistical Model
to Bridge the Gap Between Data and Decision Making

A major problem facing higher education decision makers today is how to improve the quality of their institutions in the face of dynamic change. Data about higher education institutions abound in our national data archives, but there are two major problems in using these data bases to improve institutional quality. The first problem is in the nature of the data available. One of the basic purposes of national data bases is to support institutional decision making. Yet these data bases are still largely unused for this purpose, because of limitations in the types of data available. Most existing national data bases contain administrative records type data, the majority of which are "input" variables, with few "outcome" oriented variables. These data provide very little direct information on the effects of institutional decisions.

The second problem is the lack of careful empirical studies of reputational quality which link "input" variables to "outcome" variables. In graduate education, only six major empirical studies of academic quality have been conducted in the past sixty-five years: Hughes (1925, 1934); Keniston (1959); Carter (1966); Roose and Andersen (1970); and Jones, Lindzey, and Coggeshall (1982). The latter study, often referred to as the Associated Research Councils or ARC study was conducted a decade ago. However, it remains the most recent definitive study of academic quality and is still used by leading researchers on quality.

The proposed solution to these problems is a "problem-oriented" data base, that is, a data base built specifically to study quality, which contains input variables that are statistically linked to empirically based quality output variables. Our data base, the Doctoral Institution Quality Data Base (DIQDB), contains three types of data variables: (1) **Quality Determiners** are *input variables which are associated with academic quality*, such as: student headcount, number of degrees, number of faculty, and expenditures for instruction. Data on these variables are available to institutional researchers for all higher education institutions for any given year from national data sources. (2) *Quality Indicators* are *output variables found by major research studies to be representative of academic quality*, such as: the number

of faculty publications in major journals, the number and size of research grants, and reputational or peer ratings of faculty or programs. Data on these variables are rarely available to institutional researchers, and then only for selected institutions during those years in which costly, empirical studies of quality are conducted. 3) **Proxy Quality Indicators** are *linear composites of the Quality Determiner variables*, which can be calculated in the absence of empirical Quality Indicators, that is, for years in which no empirical quality studies are performed. Calculation of a Proxy Quality Indicator requires two steps. The first step is to perform a regression analysis to obtain empirical regression weights for predicting a Quality Indicator from Quality Determiners for a year in which an empirical quality study is performed. The second step is to apply these Quality Determiner regression weights to Quality Determiner data for other years for which no empirical quality data are available.

The DIQDB research uses peer ratings of faculty as the Quality Indicator. In so doing, we are not implying that this indicator is the only useful one, or that it should be used uniformly for all institutions of higher education. We submit, however, that this indicator has an extensive research base which makes it especially useful in the context of monitoring and improving the quality of doctoral institutions and that there is substantial evidence of the reliability and validity of faculty peer ratings as quality indicators.

The largest and most recent quality studies (the Cartter, Roose-Andersen, and ARC studies) all confirmed three fundamental findings from earlier studies. *First*, peer ratings of faculty and instructional program quality are very highly intercorrelated (0.97 in the ARC study). *Second*, the reliability of faculty peer ratings is exceptionally high (in the 0.80 to 0.90 range), whether measured by correlating peer ratings of split-half groups of raters or by correlating peer ratings from two independent empirical studies. For example, the mean correlations of faculty quality peer ratings between the Cartter and Roose-Andersen studies is 0.94, and between the Roose-Andersen and the ARC studies is 0.89. *Third*, faculty peer ratings are significantly correlated with most of the other commonly accepted indicators of faculty research quality. The largest and most complete data are from the ARC study, where faculty peer ratings correlated 0.73 with numbers of articles and books published by faculty, 0.66 with estimated overall

influence of published articles, and 0.59 with the proportion of faculty holding research grants. *Finally*, faculty peer ratings correlate highly with other quality indicators, for example, faculty peer ratings correlate 0.40 with the proportion of graduates taking positions at PhD-granting institutions and 0.32 with the proportion of students holding national fellowships.

Critics of academic quality ratings, such as Astin (1985), argue that the results are produced by "academic folklore" in which some schools are deemed excellent on the basis of past reputation. On the other hand, we argue along with Jones, Lindzey, and Coggeshall (1982a, 1982b, 1982c, 1982d, 1982e) that academic quality exists and is multidimensional in nature. Quality is determined by many factors, and peer ratings are simply an effective means for having knowledgeable people synthesize all these factors into a single number.

Method

Theoretical Rationale or Model of the DIQDB

Our theoretical rationale and research methods involve five key relationships or assumptions. *First*, the quality of doctoral institutions, which can be represented by Quality Indicators, such as peer ratings on the research and scholarship of the faculty or on the effectiveness of the programs, reflects, to some degree, the policies and administrative decisions which govern the institutions. *Second*, these policies and administrative decisions are not always observable, but their nature can be inferred as "de facto policies" from the basic statistical data describing the institutions (the Quality Determiners). *Third*, the Quality Indicators and Determiners can be logically grouped into domains or groups of similar data variables commonly used to describe higher education institutions. In the DIQDB, these domains are those relating to: quality (Q); number of students (S), degrees conferred (D), and faculty (F); and amount of faculty compensation (C), expenditures (E), revenues (R), and assets (A). It is further assumed that the Quality Indicator is highly correlated with the Quality Determiners. *Fourth*, the data variables within the domains are highly redundant and can be reduced to a single "key variable." *Fifth*, the set of key variables (the Quality Indicator and the seven Quality Determiners) themselves comprise a sufficient basis

for a practical multivariate description of quality. (For more complete discussions of research procedures, see Vinsonhaler, 1986; Vinsonhaler and Vinsonhaler, 1991.)

The Initial DIQDB

The institutions represented in the DIQDB are the 170 doctoral institutions in the United States. These institutions are characterized by a significant level and breadth of activity in, and a commitment to doctoral-level education, as measured by the number of doctorate recipients and the diversity of doctoral-level program offerings (Broyles and Fernandez, 1984). Included are all major research universities in the United States. Though few in number, these institutions are the institutions where most higher education faculty and administrators earn doctorates and where much of the research and scholarship in the United States is conducted.

The initial DIQDB was created using 49 data variables (that is, 2 identification, 9 demographic, and 38 quantitative) organized into 8 domains (groups of similar data variables) for the 1981-82 academic year. The quantitative data set contained 33 Quality Determiner variables, including: student headcount by student level and time status (full-time or part-time), number of degrees conferred by degree level, number of faculty by rank, average annual compensation of faculty by rank, revenue by source of revenue, expenditures by type of expenditure, and assets by type of asset. Most of these data were obtained from the National Center for Education Statistics (NCES). The quantitative data set also contained five Quality Indicator variables. These data included faculty and program ratings from the ARC study (Jones, et. al., 1982a, 1982b, 1982c, 1982d, 1982e) and institutional quality ratings from Gourman (1983a, 1983b).

The Reduced DIQDB

The initial DIQDB was reduced in size, complexity, and redundancy by replacing each of the eight data domains with a single variable which best represented the domain and which maximized the correlation between the Quality Determiners and the Quality Indicator. Factor analysis, using appropriate methods (e.g., Harman, 1967; Mulaik, 1972), was performed, first, on the entire set of 38 quantitative variables in the initial DIQDB to confirm that the intercorrelations among the variables could be reproduced

by only 8 variables and, then, on each of the eight domains separately to confirm that a single observable variable could be selected to represent each domain with almost no information loss. The procedure used to select the 8 key variables to replace the 38 variables in the initial DIQDB was as follows. First, the faculty quality peer rating from the ARC study was selected to represent the Quality Indicator domain (Q), based on its high within-domain factor loading (0.98) and past research, described above, which demonstrated its very high reliability and validity. Second, the remaining seven key variables (the Quality Determiners) were selected, using as criteria each key variable's within-domain factor loading (reflecting its correlation with the other variables in the domain) and its correlation with the key Quality Indicator variable (Q). The eight key variables selected are summarized in Table 1.

Table 1

The Eight Key Variables Used in the DIQDB

<u>Domain</u>	<u>Variable</u>
S--Student Domain	Full-time graduate student headcount.
D--Degree Domain	Number of doctor's degrees conferred.
F--Faculty Domain	Number of full-time faculty who hold the academic rank of professor.
C--Compensation Domain	Average annual compensation of tenured professors.
E--Expenditure Domain	Expenditures for instruction.
R--Revenue Domain	Current funds revenues.
A--Asset Domain	Number of library volumes or bookstock held by an institution.
Q--Quality Domain	Aggregated ARC study disciplinary faculty quality peer ratings.

Determining the Relationship Between the Quality Determiner and Quality Indicator Variables

Since empirical quality data were available for 1982, a regression study was performed to determine the relationship between the seven Quality Determiner variables, representing the student (S),

degree (D), faculty (F), compensation (C), expenditure (E), revenue (R), and asset (A) domains and the Quality Indicator variable, representing the quality (Q) domain. Results of the step-wise multiple regression analysis, using the seven Quality Determiner variables as independent variables and the Quality Indicator variable as the dependent variable are summarized in Table 2.

Table 2

Step-wise Regression Analysis of the Eight DIQDB Key Variables

Dependent Domain/Variable = Q--Aggregated ARC Study Disciplinary Faculty Quality Peer Ratings

<u>Independent Domain\Variable</u>	<u>Beta</u>	<u>r</u>
D--Number of doctor's degrees conferred	.51	.86
A--Number of library volumes	.27	.79
C--Compensation of professors	.22	.56
R--Total revenue	.18	.77
F--Number of tenured professors	.12	.72
E--Expenditures for instruction	-.04	.74
S--Full-time graduate student headcount	-.17	.77

Multiple R = 0.91

R-Squared = 0.83

The relationship between the seven Quality Determiners and the Quality Indicator is very high. The multiple correlation (R) is 0.91, indicating that approximately 83% of the variation (R-Squared) in the key quality variable is predictable from the other seven key variables. Table 2 also shows the relative contribution (Beta) that each variable made to the regression, while controlling for other variables in the model. Major contributors were: number of doctor's degrees conferred (D), number of library volumes (A), and the compensation of professors (C). Due to the absence of newer

empirical quality studies, these regression weights (Beta) are used in DIQDB research to calculate Proxy Quality Indicators for doctoral institutions for analytical and planning purposes.

Updating the DIQDB

Major criteria used in the design of the DIQDB are that the data base must be:

(1) *comprehensive*, given the limits of the research; (2) *maintainable* on a commonly available personal computer; and (3) *open-ended*, so that the data base can be periodically updated and/or expanded with new or revised information. These criteria are important in ensuring that the DIQDB can be easily and inexpensively updated, so that the impact of past and future decisions on institutional quality can be determined.

The first update of the DIQDB used 1985-86 academic year data, so that change over the four-year period between 1982 and 1986 could be determined. For the 1986 update, it was only necessary to input data for the 8 key variables, rather than for the 38 variables used in the initial DIQDB. Data sources for the 1986 update were identical to those used in 1982, except for the Quality Indicator. As was noted above, no empirical quality study has been conducted since 1982, so no Quality Indicator data were available for 1986. Therefore, a *Proxy Quality Indicator* was calculated for each institution, as follows. First, for any given institution, a regression term was calculated for each of the seven Quality Determiners by multiplying the institution's 1986 standard score value for each Determiner by the Determiner's 1982 regression coefficient (Beta). Second, these seven regression terms were summed to yield a Proxy Quality Indicator for the institution. The same procedure used for updating the DIQDB for 1986 can be used in updating the DIQDB for other years.

Results

The DIQDB Profile Analysis

The profile analysis method is used in DIQDB research to analyze and report on institutional quality. This method graphically displays a *profile* of the basic statistical characteristics of a doctoral institution or group of doctoral institutions by charting standard score values for the DIQDB key

variables, representing the eight data domains. A standard score is calculated as follows:

$$\begin{array}{lcl} \text{Standard score} & & \text{Raw score for a} \\ \text{for a doctoral} & & \text{doctoral institution} \\ \text{institution} & & \text{Mean raw score for all} \\ \text{on the key} & = & \text{doctoral institutions} \\ \text{variable} & & \text{on the key variable} \\ & & \text{Standard deviation of the raw scores for all} \\ & & \text{doctoral institutions on the key variable} \end{array}$$

Standard scores, as calculated above, have a mean of zero and a standard deviation of one. These scores are transformed to have a mean of 50 and a standard deviation of 10 to facilitate interpretation of the profiles. The United States average of the key variables is represented as a straight line with a constant value of 50; a doctoral institution with a score of 60 on a key variable would be one standard deviation above the average on that variable and an institution with a score of 40 would be one standard deviation below the average. The standard score for a group of doctoral institutions, such as all the doctoral institutions within a state or region, is the average of the standard scores for all of the doctoral institutions in the group.

When interpreting the profiles, two characteristics should be noted. *First*, the overall *profile level* (that is, the deviation of the profile above or below the average for the one hundred and seventy United States doctoral institutions) reflects the *size of the institution* on each of the key variables. As can be seen from the profiles, institutional size is not constant across variables. Thus, artifacts induced, when controlling for size by dividing variables by some common base (for example, student headcount) when institutional comparisons are made, are apparent. *Second*, the *configuration or shape of the profile* of an institution reflects the *internal policies and priorities* of the institution, regardless of its size. Both of these characteristics can be easily seen and are considered when institutional comparisons are made in DIQDB research.

Five example DIQDB profiles, which are typical of our findings for individual and groups of doctoral institutions, are used below to demonstrate some of the ways higher education policy makers and planners can use these profiles to analyze and determine the *impact of past or alternative decisions* on institutional quality. When looking at the profiles, remember that the Quality Indicator (Q)

for 1982 is an empirical value from the ARC study, while for 1986, it is a calculated proxy value.

Using DIQDB Profiles to Determine the Impact of Past Decisions on Institutional Quality

Figure 1 shows the impact of past decisions *over a four-year time period*, 1982 to 1986, on the quality of a *single public institution*, the University of California-Berkeley (UC-Berkeley).

Put Figure 1 about here

Looking at Figure 1, we, first, see from the profile levels that UC-Berkeley is somewhat larger than the average doctoral institution. Second, we see from the profile configurations that institutional policies and administrative decisions, reflected by the key variables, have changed very little over the four-year period. From the profile configurations, we also see that there appears to be an imbalance between program needs and program resources which could potentially affect the quality of the institution. That is, program demands have increased (full-time graduate headcount, degrees conferred, and number of tenured professors have all gone up), while programming support has declined (expenditures for instruction and the average compensation of Professors have gone down) due to virtually static resources (total revenue has remained almost the same). Quality appears not to have been affected thus far, but this demand-resource imbalance should be carefully monitored in the future.

Figure 2 shows the profiles of *two public institutions*, UC-Berkeley and Michigan State University (MSU), *during a single year* (1986).

Put Figure 2 about here

Our analysis of Figure 2 is as follows. Both of the institutions are large, as can be seen from the profile levels (that is, all of the key variables, except the average annual compensation of

professors at MSU, are above the national average). Both institutions also have similar resources (total revenue) and spend about the same amount on instruction (expenditures for instruction). However, there are, also, profound differences between the two institutions. For example, from the profile configurations, we see that UC-Berkeley enrolls substantially more full-time graduate students; grants more doctor's degrees; has a larger library to support its students; has fewer, but higher paid, faculty; and has a higher faculty quality rating, than does MSU. It should be noted here that, relative to the national average, the faculty quality ratings for both UC-Berkeley and MSU are substantially higher than the compensation paid to professors at these institutions. This may be indicative of a potential pay problem (e.g., salary compression or undervaluing of quality faculty). Therefore, employment and compensation policies and practices should be carefully reviewed by these institutions to prevent future damaging faculty recruitment and retention problems.

Figures 3 and 4 show *profiles for groups of doctoral institutions* (that is, the average of all of the doctoral institutions in two states, California and Michigan, respectively) for 1982 and 1986.

Put Figures 3 and 4 about here

As can be seen from Figures 3 and 4, the profiles for the two states reflect many of the same characteristics seen above in the institutional profiles. For example, the two state profiles have remained remarkably stable over the four years and total revenue and expenditures for instruction for institutions within the two states are comparable, but differing policies and administrative decisions governing the selection and compensation of faculty are even more apparent here. California doctoral institutions also have a higher faculty reputational quality rating than Michigan doctoral institutions.

The profiles also show that change does occur. For example, institutional downsizing is apparent in the Michigan profile, where six of the eight key variables (that is, full-time graduate headcount, number of doctor's degrees conferred, number of tenured professors, compensation of

professors, expenditures for instruction, and number of library volumes) all declined relative to the national average during the four-year period. That such downsizing can be beneficial to the quality of an institution, can be seen in the slight increase in Michigan's faculty quality rating.

Using DIQDB Profiles to Determine the Impact of Alternative Decisions on Institutional Quality

The final figure (Figure 5) shows the impact of alternative decisions on institutional quality. This figure compares UC-Berkeley's 1986 actual profile, previously seen in Figures 1 and 2, to its 1986 *simulated profile*. The simulated profile shows a \$7,560,000 (1.22%) increase in revenue, utilized solely to increase the number (40) and compensation (\$5000) of tenured professors. Note that this revenue increase also caused a concomitant increase (\$7,560,000) in expenditures for instruction.

Put Figure 5 about here

As can be seen from Figure 5, this small increase in revenue, which could be obtained in a variety of ways (e.g., from an increase in tuition, state appropriations, or research contracts), could bring into better balance program needs and program resources. This example demonstrates that even a small increase in revenue, if spent in accordance with the model, can yield significant projected or anticipated effects on academic quality over the short-term.

Conclusions

Perhaps, the major conclusion we would like to draw from these results is that the DIQDB Profile Analysis represents a promising new method for viewing the nature of the American doctoral institution and, perhaps, of institutions of higher education, in general. In support of this, we note the following findings. *First*, the profiles are stable over time, indicating that decision makers desiring to make major quality changes in their institutions, need to engage in long-term decision making. Such decision making requires strategic planning, based on the linkage of data, information (synthesized data), and knowledge (interpreted information). Strategic planning will be critical for institutions

desiring to remain competitive in the next century.

Second, the profiles reflect, to some degree, major national trends (e.g, declining institutional revenues, institutional downsizing, and faculty pay problems). Early identification of such trends, through such methods as the DIQDB Profile Analysis, may help decision makers to modify or reverse their effects.

Third, the profiles have uncovered what appears to be major institutional, state, and regional policy differences, for example, hiring/retaining large numbers of senior faculty at low compensation rates versus hiring fewer senior faculty at higher compensation rates. This difference may be appropriate (based on the quality of the faculty) or inappropriate (based on an undervaluation or under-compensation of quality faculty). If, the latter is the case and the size and quality of the faculty pool diminishes in the future, as predicted, some institutions may have difficulty recruiting and retaining quality faculty.

Fourth, the profiles show a high association between faculty compensation and faculty reputational quality. This finding should be viewed with caution, since correlation does not mean causation and the effect may be due to other factors which are simply correlated with both compensation and faculty reputational quality. However, institutions who profess to be "high quality" and whose faculty are rated "high-quality" by their peers, but who pay their faculty at low rates, should carefully review their compensation policies and practices to prevent potentially damaging public relations or other problems.

Fifth, the profiles reflect the strength of the relationship between the Quality Determiners as a group and the Quality Indicator. Understanding this relationship can help decision makers to focus on those areas which are most important to the achievement of quality goals.

Finally, the profiles reinforce the quality strategy already used by high-quality doctoral institutions, such as UC-Berkeley: recruit high quality full-time graduate students and provide them with quality senior faculty and adequate resources (e.g., a large library), so that they persist to graduation.

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Figure 1

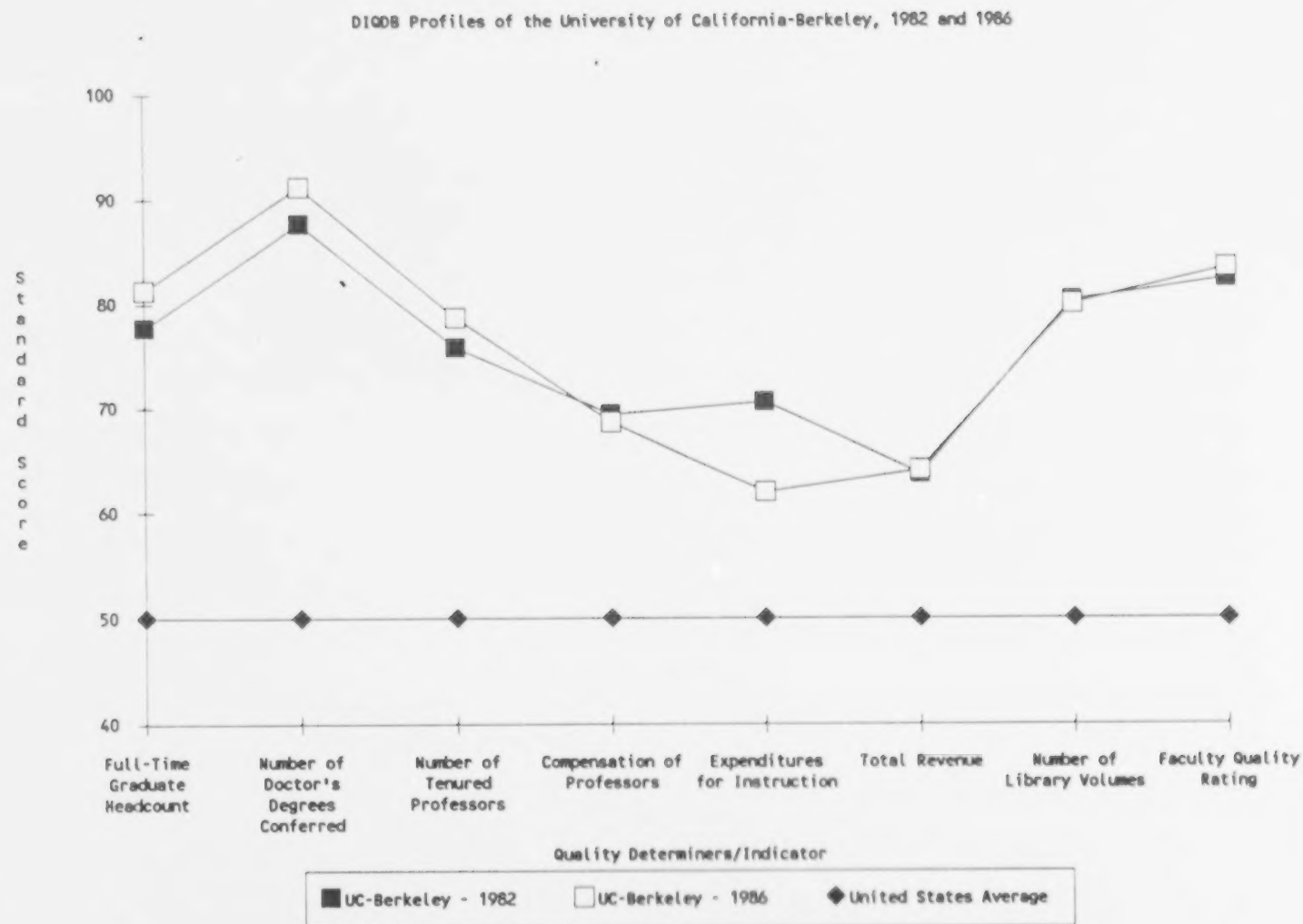


Figure 2

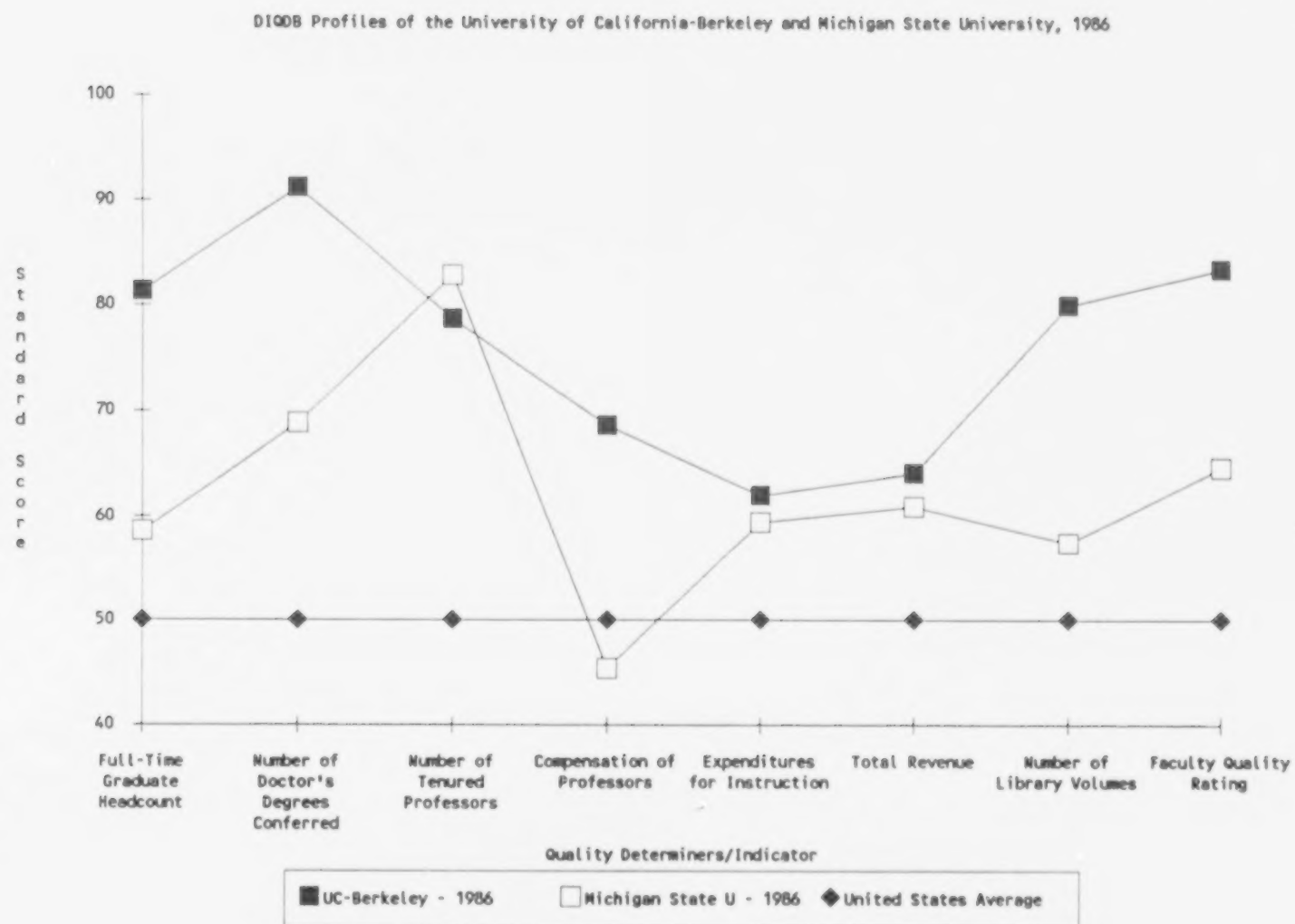


Figure 3

DIQDB Profiles of the Average State of California Doctoral Institution, 1982 and 1986

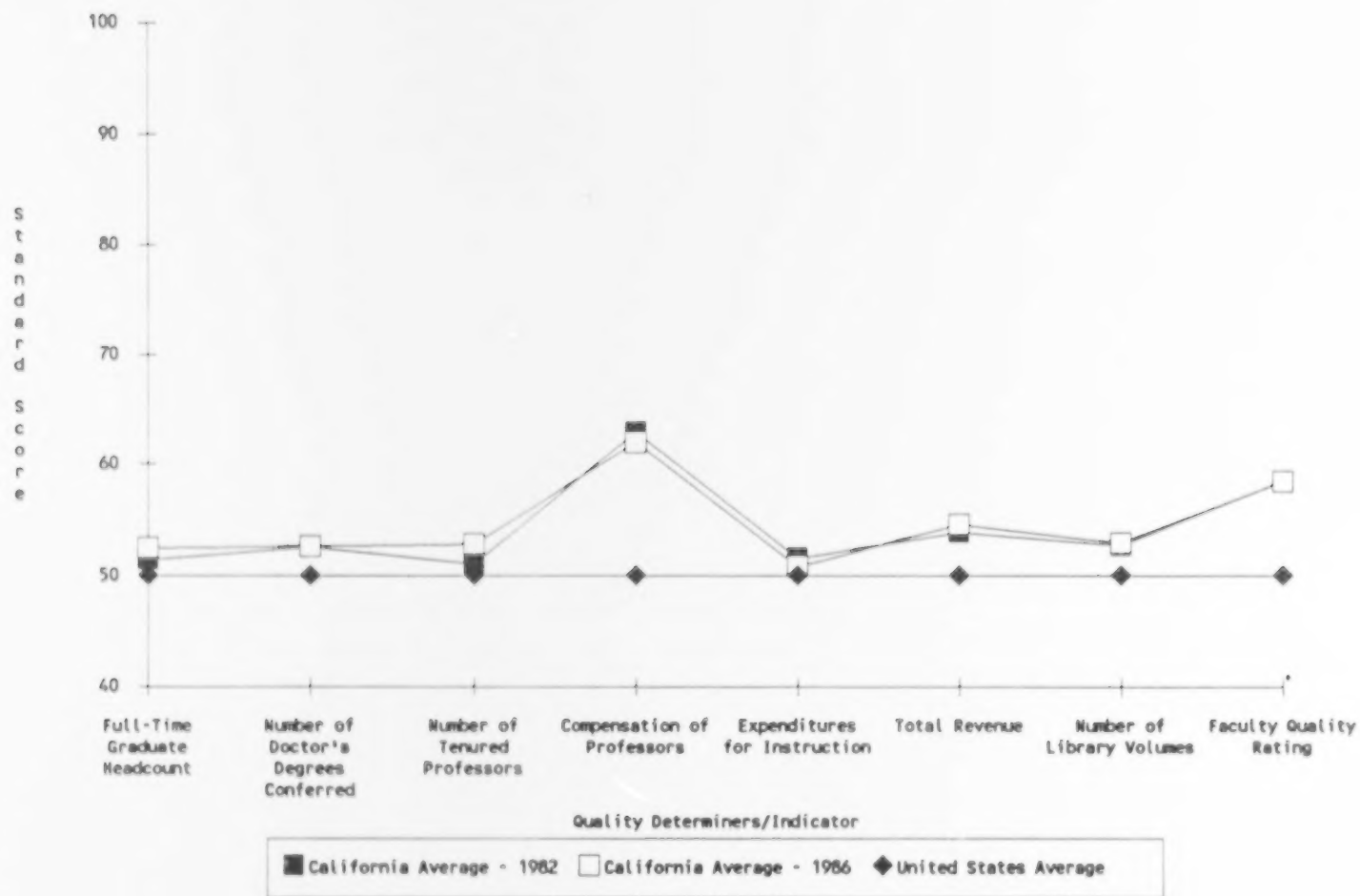


Figure 4

DIQDS Profiles of the Average State of Michigan Doctoral Institution, 1982 and 1986

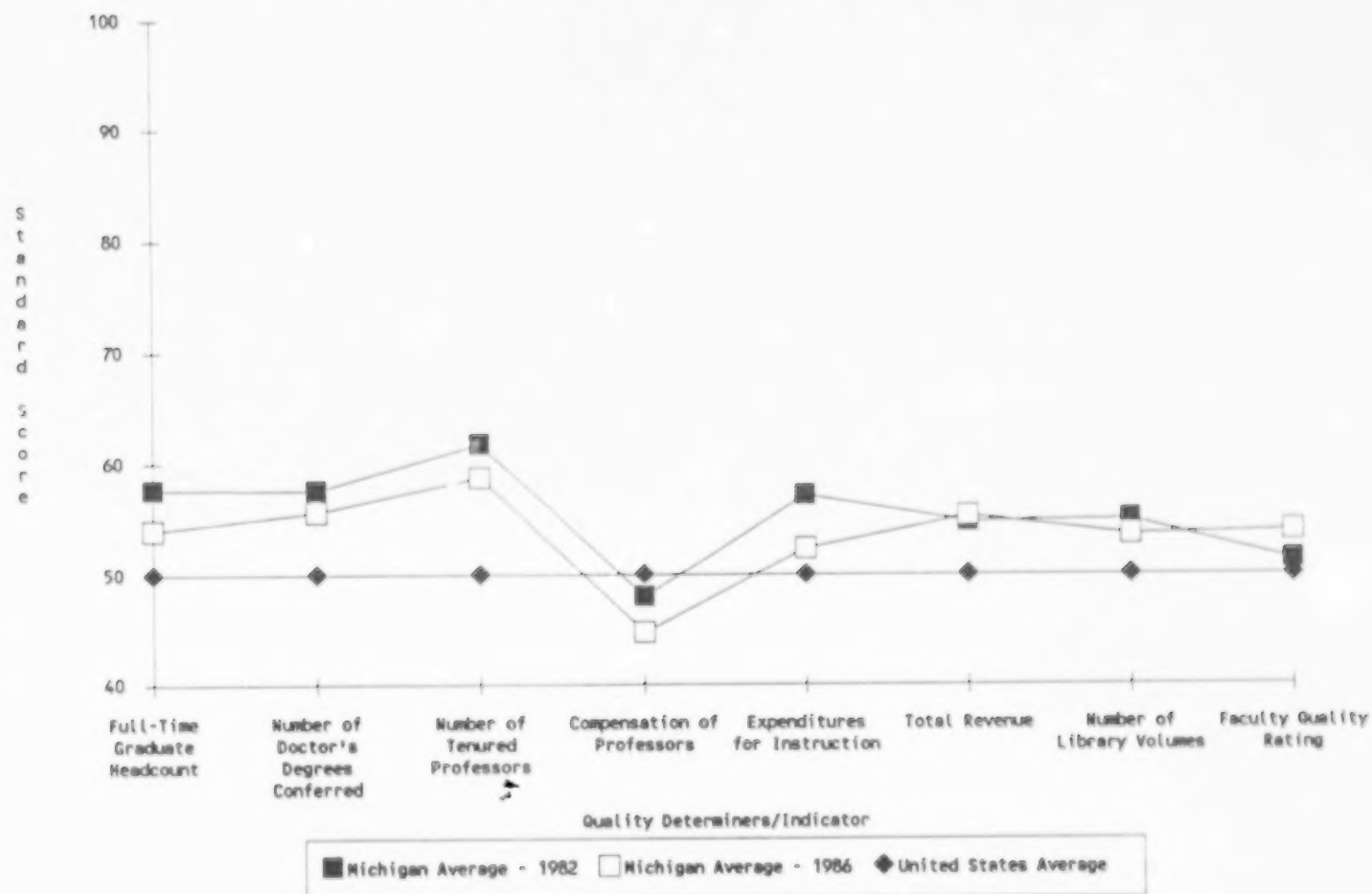


Figure 5

